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# SILVICAL CHARACTERISTICS of WESTERN HEMLOCK

by CARL M. BERNTSEN

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COVER: A pure western hemlock stand on the Cascade Head Experimental Forest, Oreg. The stand is 105 years old, has about 200 trees per acre, and a volume of over 100,000 board-feet per acre, Scribner rule.

# SILVICAL CHARACTERISTICS OF WESTERN HEMLOCK

by

Carl M. Berntsen

Willamette Research Center[1/]

Western hemlock (Tsuga heterophylla)[2/] grows along the Pacific Coast from Prince William Sound in Alaska to northern California. It also ranges inland in a narrow, scattered pattern along the United States-Canadian border and then spreads out fanlike through northeastern Washington, northern Idaho, northwestern Montana, and throughout the Selkirk Mountains of southeastern British Columbia (fig. 1). Best stands are found in the humid coastal regions of Oregon, Washington, British Columbia, and Alaska, and on the lower slopes of the Cascade Range in Oregon and Washington.

Western hemlock has a variety of common names, some of which were adopted to disguise it from eastern hemlock for marketing purposes. Some of these are: west coast hemlock, Pacific hemlock, hemlock spruce, western hemlock spruce, western hemlock fir, gray fir, silver fir, and Alaska pine.

## HABITAT CONDITIONS

### Climatic

Western hemlock thrives best in the humid and mild climate along the Pacific slope, where frequent fogs and rain provide moisture during the growing season. Average annual precipitation in the coastal hemlock region varies from over 100 inches in parts of Alaska and Washington to 38 inches near its southern limit at Eureka, Calif. (table 1). Average precipitation during April to September ranges from 5.5 inches at its southern limit to 65.5 inches at Cordova, Alaska. In the northern Rocky Mountain region, precipitation ranges from 25 to 53 inches a year. Dry summers

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[1/] Maintained at Corvallis in cooperation with the School of Forestry, Oregon State College.

[2/] Scientific and common names of trees in this publication follow: Little, Elbert L., Jr. Check list of native and naturalized trees of the United States (including Alaska). U. S. Dept. Agr. Handb. 41, 472 pp. 1953.

Figure 1.--Range of Western Hemlock.

Table 1.--Climatological data[1/] for locations within the commercial range of western hemlock

| Location | Elevation | Average precipitation | | Temperature | | | | | Frost-free days |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Average | | | Absolute | | |
| | | April-Sept. | Annual | Annual | Jan. | July | Maximum | Minimum | |
| | Feet | Inches | | Degrees F. | | | | | Number |
| Coastal range: | | | | | | | | | |
| Alaska: | | | | | | | | | |
| Seward | 76 | 28.4 | 73.7 | 39.5 | 22.4 | 55.3 | 82 | -20 | 132 |
| Cordova | 40 | 65.5 | 145.4 | 38.6 | 27.2 | 54.8 | 87 | -19 | 149 |
| Sitka | 15 | 34.7 | 87.1 | 45.6 | 32.4 | 54.9 | 87 | - 5 | 159 |
| Wrangell | 37 | 31.0 | 83.0 | 43.9 | 29.0 | 58.2 | 92 | - 6 | 169 |
| Ketchikan | 10 | 57.5 | 150.9 | 46.4 | 32.6 | 57.5 | 96 | - 8 | 165 |
| British Columbia: | | | | | | | | | |
| Masset | 30 | 20.8 | 53.9 | 45.6 | 35.8 | 58.1 | 84 | - 2 | 169 |
| Vancouver | 136 | 15.9 | 58.7 | 49.0 | 35.6 | 63.3 | 92 | 2 | 219 |
| Washington: | | | | | | | | | |
| Quinault | 220 | 29.9 | 128.6 | 50.9 | 38.4 | 63.5 | 104 | 11 | 208 |
| Aberdeen | 135 | 18.7 | 82.9 | 49.9 | 39.2 | 59.6 | 105 | 6 | 191 |
| Oregon: | | | | | | | | | |
| Astoria | 220 | 17.0 | 77.5 | 51.2 | 40.3 | 60.9 | 97 | 10 | 273 |
| Newport | 115 | 15.0 | 66.2 | 50.9 | 43.7 | 56.8 | 100 | 1 | 248 |
| California: | | | | | | | | | |
| Eureka | 64 | 5.5 | 37.6 | 51.5 | 47.3 | 56.1 | 85 | 20 | 328 |
| Inland range: | | | | | | | | | |
| Idaho: | | | | | | | | | |
| St. Maries | 2,200 | 6.5 | 25.1 | 47.3 | 28.1 | 67.2 | 106 | -26 | 137 |
| Priest River Expt. Forest | 2,380 | 7.5 | 28.9 | 43.2 | 23.3 | 64.2 | 102 | -30 | 97 |
| Bonners Ferry | 1,787 | 5.9 | 21.5 | 44.0 | 21.7 | 65.3 | 102 | -26 | 143 |
| Avery | 2,500 | 8.4 | 31.7 | 46.8 | 26.4 | 67.1 | 108 | -25 | 112 |
| British Columbia: | | | | | | | | | |
| Revelstoke | 1,497 | 13.3 | 39.7 | 43 | 21 | 65 | 105 | -30 | 2/ |
| Glacier | 3,778 | 16.9 | 53.2 | 36 | 14 | 58 | 95 | -32 | 2/ |

1/ Compiled from U. S. Weather Bureau records and from weather records, Dept. of Agr., British Columbia.
2/ Not available.

in this region usually limit the occurrence of western hemlock to the northerly slopes and moist creek bottoms.

Minimum temperatures below -20° F. occur occasionally in the inland range in Idaho, Montana, and British Columbia, and also in parts of Alaska; but elsewhere, especially in the coast region south of Alaska, minimum temperatures are generally above zero. Maximum temperatures range from 82° F. at Seward, Alaska, to 105° F. at Aberdeen, Wash., in the coastal forests, and from 100° F. to 108° F. in the northern Rocky Mountain Region.

Thornthwaite (21)[3/] classifies the coastal region in the superhumid zone, and the area between the summits of the Coast and Cascade Ranges with the interior region in the humid zone.

## Edaphic

Western hemlock is not too particular as to soil requirements. In general, however, the better the soil the better the growth. It occurs on a wide variety of soils derived from sandstones, shales, and igneous rock material, but prefers deep, internally well-drained soil under high rainfall conditions. Soil reaction ranges between pH 4.5 and 5.0 along the coast of Oregon and Washington, whereas in Alaska soil pH beneath western hemlock is generally between 3.5 and 4.0. In the white pine type, western hemlock grows in soils with a pH of about 5.5 and occasionally occurs on sites with a pH of 6.0. Soil types of western Oregon and western Washington on which hemlock grows include: Astoria, Melbourne, Olympic, St. Helens, Stabler, Elma, and Nawhatzel.

In the arborvitae-hemlock vegetational zone of northern Idaho, soils were found to be derived mainly from the Idaho batholith and represented by the Belt series (8); rocks being largely quartzitic and argilaceous in the former, and quartz manzonite and granite types in the latter. These soils, which were only weakly acid (pH 6), resembled most closely the brown podzolic soils.

## Physiographic

Best development of hemlock is at elevations between sea level and 2,000 feet along the coast from Alaska to Oregon. In the northern

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[3/] Underscored numbers in parentheses refer to Literature Cited.

Rocky Mountain Region of Idaho and Montana, it is found at altitudes up to 6,000 feet (17). In the Selkirk Mountains of British Columbia, it ranges up to 5,000 feet (23). Trees become stunted at the extreme elevations even when good soil and moisture are available. It grows at higher elevations (above 3,500 feet) in the southern part of its range (Washington, Oregon, and California) than toward its northern limit in Alaska (19).

## Biotic

Western hemlock is usually subordinate in association with other conifer species, but sometimes dominates and occasionally occurs in pure stands along the Pacific Coast slopes. From the upper slopes of the coastal mountains and through its inland range, western hemlock generally occurs in scattered patches, groups, or singly through the forest. According to the Society of American Foresters' classification of forest cover types, it is one of the major components of the five following types (18):

| Type No. | Name |
|---|---|
| 224 | Western hemlock |
| 225 | Sitka spruce--western hemlock |
| 226 | Pacific silver fir--hemlock |
| 227 | Western redcedar--western hemlock |
| 230 | Douglas-fir--western hemlock |

In the western white pine type, western hemlock is one of the principal associates, although comprising only 3 percent of the stand composition. Here it frequently performs a dual role, with part of the trees in the dominant stand and the remainder forming a distinct understory (11).

Western hemlock also occurs as a minor component of many other types such as red alder, mountain hemlock--subalpine fir, and Engelmann spruce--subalpine fir.

In some dense stands, scarcely any herbaceous or shrubby vegetation is present. Where light penetrates to the forest floor, however, certain ferns, herbs, and shrubs occur. Shrubs present in abundance are salmonberry (Rubus spectabilis),[4/]

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[4/] Scientific and common names of shrubs and herbs in this publication follow: Kelsey, Harlan P., and Dayton, William A. Standardized plant names. Ed. 2, 675 pp. Harrisburg, Pa. 1942.

blueberry[5] (Vaccinium sp.), red whortleberry[5] (Vaccinium parvifolium), salal (Gaultheria shallon), coast rhododendron (Rhododendron macrophyllum), Oregongrape (Mahonia acquifolium), and American devilsclub (Oplopanax horridus). Vine maple (Acer circinatum), although classified as a tree, is also a common shrub-like associate. Occasionally, under partially opened stands, brush is replaced with a dense stand of hemlock reproduction.

Shrub species characteristic of hemlock stands of the inland range are not so evident due to the scattered occurrence of this tree species. However, the frequent incidence of devilsclub on moist sites under hemlock stands (7) shows that a close alliance exists between these species for site requirements over much of the western hemlock range.

## LIFE HISTORY

### Seeding Habits

Flowering and Fruiting.--Male flowers occur in catkins borne in the axils of the previous year's shoots; the female flowers that develop into cones are borne at the ends of the previous year's lateral shoots (22). Records from 14 stations in western Washington and western Oregon[6] show that pollen shedding begins between April 22 and May 13 and ends between May 3 and May 25. In southeastern Alaska, pollen shedding begins about a month later but does not extend over as long a period.

The small, solitary, drooping cones are composed of thin, overlapping scales. They ripen during the first year, but remain on the tree after release of seeds until summer or autumn of the second year. Cones are 3/4 to 1-1/4 inches long at maturity and hold approximately 30 to 40 seeds each. Seeds are small, about a sixteenth of an inch long, and are attached to a thin wing one-fourth inch long. About 300,000 dewinged seeds is an average number per pound.

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[5] Commonly called huckleberry in the Pacific Northwest.

[6] Average day of year on which given phenological development occurred in given species at points in Oregon and Washington. Dec. 9, 1952. (Unpub. data. On file U. S. Forest Serv., Pac. NW. Forest and Range Expt. Sta., Portland, Oreg.)

Seed Production. --Western hemlock is a very prolific seeder. It produces some seed every year and heavy seed crops every 3 or 4 years. Germinative capacity of the cleaned seed is about 55 percent (22). Cones are sometimes found on trees less than 20 years old, but minimum commercial seed-bearing age usually starts between 25 and 30 years. Open-grown trees frequently acquire a hue ranging from purple to bronze as the result of a heavy cone crop adorning the full length of the crown. Even trees in dense stands produce heavy cone crops.

Records on the Oregon Coast showed that more than 8 million viable seeds per acre were released during each of 2 years from 100-year-old stands (16), or about 27 pounds per acre annually. A bumper crop in Alaska during 1951 produced 91 pounds of seed per acre in a spruce-hemlock forest; 86 pounds were hemlock seed (10). In stands on Vancouver Island, with only two-thirds as many stems as its associate Douglas-fir, understory hemlock produced three times as many seeds (9). Here, more than half the hemlock seed was retained on the trees until spring. In its inland range as well, hemlock consistently outproduces white pine and its principal associates in both frequency of cone crops and quantity of seed. This characteristic explains in large part the abundance of western hemlock in certain parts of the white pine type (11).

Seed Dissemination. --Hemlock seed may be carried considerable distances by wind. When released at 200 feet elevation in a 12.5 m.p.h. wind, seed traveled as far as 3,800 feet, but heaviest seed fall was found 2,000 feet from point of release (12). Under ideal conditions, western hemlock seed is probably blown more than a mile from its source. However, 10 to 15 times as much seed falls to the forest floor under a dense stand than on adjacent clear-cut openings within 400 feet of timber's edge (9, 16).

Cones generally begin to open between September 3 and October 6, but reports from one area on the Oregon Coast show that seed fall consistently began during the latter part of October (16). In this area, seed fall is greatly accelerated during periods of dry offshore winds, but may be extended over a period of several months or even postponed until late fall or winter if moist southwest storm winds persist.

There is not much known of extent of seed destruction by insects, diseases, or animals although only a small percentage of the seed produced usually germinates. Seed chalcids (Megastigmus spp.)

infest hemlock seeds but extent of damage has not been determined. Seed-eating rodents are believed to cause the greatest seed losses, although diseases also take their toll.

## Vegetative Reproduction

Propagation is commonly from seed, but western hemlock can be propagated by layering and from cuttings (6). It does not sprout from roots or stump.

## Seedling Development

Establishment.--If adequate moisture is available, germination under forest conditions is excellent on such diverse materials as moss, humus, decaying litter, and mineral soil. Seedlings are often abundant under mature stands and also on moist seedbeds in open or clear-cut areas. In the coastal region, where the forest floor is often deeply covered with herbs, ferns, and shrubs, the small seeds of western hemlock often find favorable conditions for germination restricted mainly to stumps and trunks of fallen trees. On these seemingly precarious seedbeds some seedlings survive, root into the ground around or through the stump or trunk, and eventually grow to maturity.

Seedling mortality may occur from drought, heat injury to the stem, frost, insects, disease, and vegetative competition. Animal damage to seedlings is usually a minor problem, although deer browsing is common in some areas. Rabbits and mountain beaver also feed on hemlock seedlings in some areas. Occasionally mice will chew the bark off seedling stems. In the white pine type, hemlock is considered most susceptible to drought; resistance to drought being linked closely with depth of initial root penetration (11). In the nursery bed, hemlock seedlings are comparatively free from injurious pests but may be attacked by damping-off (22).

Because western hemlock is highly tolerant and germinates and survives under a wide variety of seedbed conditions, natural regeneration can be obtained through harvesting methods varying all the way from individual tree selection to clear cutting. Clear cutting in patches, with dependence on surrounding timber as a source of seed, is the most common harvesting method in the spruce-hemlock type. On the Oregon Coast, patch cuttings as large as 80 acres in size have been successfully regenerated by this method (16).

Slash burning is generally not necessary to aid seedling establishment, but is frequently used to reduce fire hazard, retard brush development, and expose mineral soil for seedbeds of associated species when mixed stands are desired. Slash burning can be detrimental if large numbers of healthy advanced reproduction occupy the site.

Shelterwood cuttings provide favorable conditions for hemlock regeneration, but must be used cautiously where there is danger of exposing the stand to wind damage or where a preponderance of hemlock in the stand is not desired, as in the white pine type.

Early Growth.--Height growth of western hemlock seedlings is usually slow during establishment. On the Oregon Coast, 3-year-old seedlings that were free to grow averaged only 6 to 7 inches in height (3). Near Grays Harbor, Wash., 2-0 planting stock grew only 2 inches during a 2-year period following planting (24). After establishment, however, western hemlock grows rapidly in height if subject to full overhead light. A height growth of 2 feet annually is not uncommon.

## Sapling Stage to Maturity

Growth and Yield.--Twenty-year-old stands of western hemlock may contain 2,000 stems per acre or more, with volumes from 400 cubic feet per acre on poor sites to 2,600 cubic feet on the best sites. Tree measurements and volumes for 100-year-old stands in Oregon and Washington are shown in table 2. Cubic-foot yields of western hemlock stands in British Columbia and Alaska for a given site are quite similar to those of stands in Oregon and Washington, but board-foot yields decrease progressively northward. The northern stands have more trees per acre, but average tree diameter is less. It is significant, also, that sites I and II become increasingly scarce toward the northern limits of coastal western hemlock stands.

Under the best growing conditions, trees attain a diameter of 3 to 4 feet and a height of 175 to 225 feet. Larger trees are found, but those over 5 feet in diameter are rare.

Chief causes of mortality in young-growth western hemlock are wind and snow. Losses from snow-break are most severe in the inland range, especially in thinned stands (11); wind is the main cause of loss in coastal forests. In dense stands, a large number of trees also die from suppression during stand development.

Table 2.--Average tree dimensions, density, and timber volumes per acre for fully stocked 100-year-old western hemlock stands in Oregon and Washington[1/]

| Site class | Average tree | | Density (trees per acre[2/]) | Volume per acre | | |
|---|---|---|---|---|---|---|
| | D.b.h.[2/] | Height[3/] | | Cubic[2/] | International 1/8" rule[4/] | Scribner rule[5/] |
| | Inches | Feet | Number | Cu.ft. | Bd.-ft. | Bd.-ft. |
| I | 23.2 | 200 | 121 | 25.3 | 187,000 | 152,000 |
| II | 21.6 | 170 | 137 | 21.4 | 157,000 | 127,000 |
| III | 19.4 | 140 | 166 | 17.4 | 129,000 | 99,000 |
| IV | 16.5 | 110 | 213 | 13.3 | 98,000 | 72,000 |

[1/] Barnes, George H. Yields of evenaged stands of western hemlock. Pac. NW. Forest and Range Expt. Sta. 1953. (Manuscript being prepared for publication by U. S. Dept. Agr.)

[2/] All trees 1.6 inches d.b.h. and larger.

[3/] Average height of dominant and codominant trees only.

[4/] All trees 6.6 inches d.b.h. and larger.

[5/] All trees 11.6 inches d.b.h. and larger.

Reaction to Competition. --Western hemlock is rated by Baker as very tolerant (2) and is placed in about the same tolerance class as Port-Orford-cedar (Chamaecyparis lawsoniana), Pacific silver fir (Abies amabilis), and Pacific yew (Taxus brevifolia). In the coastal forests, western hemlock is believed to be more tolerant than Port-Orford-cedar but less tolerant than Pacific silver fir.

Hemlock usually responds well to release after long periods of suppression. Meyer (14) found that 50-year-old understory reproduction developed into a vigorous young-growth stand following complete removal of the overstory. In contrast, poor response to release of suppressed trees over 100 years old has been noted in Alaska (1, 20). When western hemlock develops in a dense even-aged stand, natural pruning takes place early. Under these conditions tree crowns are usually narrow and short, and trunk development is favorable. When given unrestricted growing space, however, or if it develops as an understory tree, the quality of western hemlock is substantially reduced by persistent branches and poor form.

The pure western hemlock forest is a true climax type; theoretically it is a climax forest that follows the subclimax types of Sitka spruce (Picea sitchensis) and Douglas-fir (Pseudotsuga menziesii) west of the Cascades, and western white pine (Pinus monticola) in the northern part of its inland range. Sitka spruce, western redcedar (Thuja plicata), and Pacific silver fir are three species that sometimes persist in the hemlock climax type.

Damaging Agents. --A number of trunk butt and root rots (including Fomes annosus, Fomes pini, Poria weirii, Poria subacida, Echinodontium tinctorium, and Polyporus circinatus) are common on western hemlock (4). These decays are usually much more destructive in old-growth than in young-growth stands. In the inland range, however, infection by Echinodontium tinctorium (Indian paint fungus) often occurs comparatively early in the life of the tree. In a study by Hubert[7/] infection was first detected in trees 41 to 80 years of age. Forty-six percent of the trees in this age group were infected. Susceptibility of hemlock to this heart rot is largely responsible for the frequent classification of this tree as an inferior species in the western white pine type (11).

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7/ Hubert, Ernest E. First progress report on the study of decay in western hemlock. 1929. (Unpublished report, U. S. Forest Serv., Region 1.)

Dwarfmistletoe (Arceuthobium campylopodum) is a common parasite on western hemlock. It increases mortality, especially of mature trees, and reduces growth in trees of all sizes.

The most important insects that attach western hemlock are the hemlock looper (Lambdina fiscellaria), the black-headed budworm (Acleris variana), the western larch roundheaded borer (Tetropium velutinum), and the hemlock sawfly (Neodiprion tsugae) (13).

Four of five major outbreaks of the hemlock looper have occurred along the coast of Oregon, Washington, and British Columbia during the last 60 years. The most recent outbreaks occurred between 1943 and 1945 on the Oregon Coast and covered some 12,000 acres with a timber loss of 40 million board-feet. The epidemic was halted by aerial spraying with DDT. An outbreak of the black-headed budworm in Washington in 1944 and 1945 resulted in large acreages of defoliated trees, but only a small amount of killing. On Vancouver Island, British Columbia, however, an outbreak in the early 1940's killed a large volume of western hemlock. In 1957, a second large outbreak covering some 150,000 acres and threatening about 3 billion board-feet of hemlock is believed to have been controlled by aerial spraying with DDT.

The western larch roundheaded borer is an important killer of hemlocks that have been weakened by defoliators such as the looper and black-headed budworm. It continues to kill trees in large numbers for several years following the end of defoliator outbreaks. The hemlock sawfly occasionally becomes epidemic and defoliates extensive areas along the Pacific Coast.

Fire and wind also cause considerable losses in western hemlock stands. Thin bark and occurrence of exposed roots are reasons for a high rate of susceptibility to fire damage. Losses from wind are due mainly to the shallow rooting characteristic of this species.

## SPECIAL FEATURES

Western hemlock is relatively easy to recognize because of such features as lacy foliage, drooping leader, and fluted trunks. The latter is believed to be associated with suppressed stands that have been released (14). Silvicultural practices are influenced in varying degrees by such characteristics as shallow rooting, thin bark, and heavy and frequent seed crops. The bark of this species contains a relatively high tannin content of 12 to 22 percent (5).

## RACES AND HYBRIDS

The wide geographical distribution of western hemlock and the variable climatic conditions under which it grows would seem to indicate the occurrence of variable forms of this species. However, the only suspected variation occurs from a natural cross between western hemlock and mountain hemlock (Tsuga mertensiana) (15). It is reported that both assumed parents are found growing together in the Mount Baker area. Natural specimens of this hybrid are not easily recognized, probably being passed over as a green-leaved form of mountain hemlock (6).

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